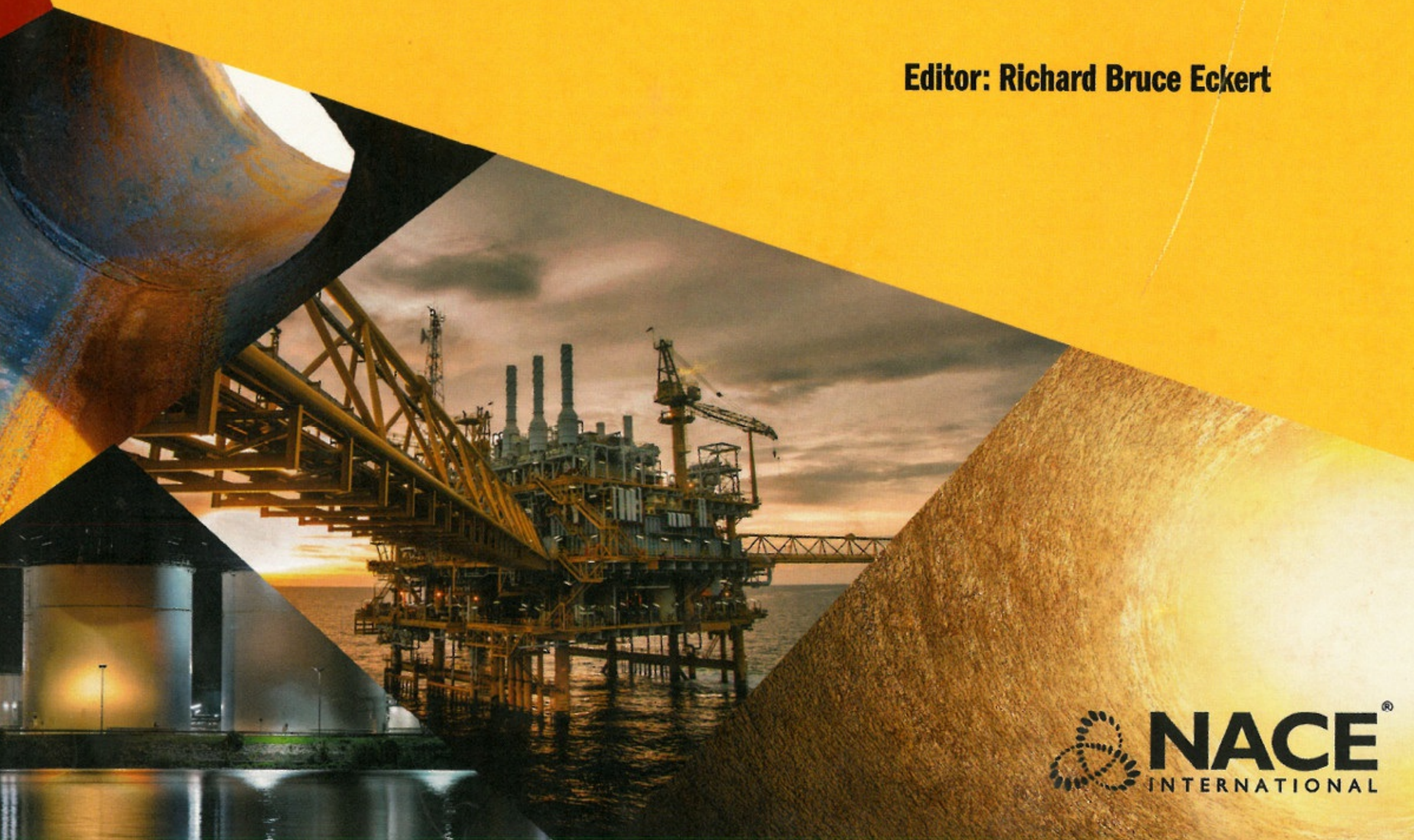
CorrCompilations

Introduction to Managing MICROBIOLOGICALLY INFLUENCED CORROSION

Editor: Richard Bruce Eckert



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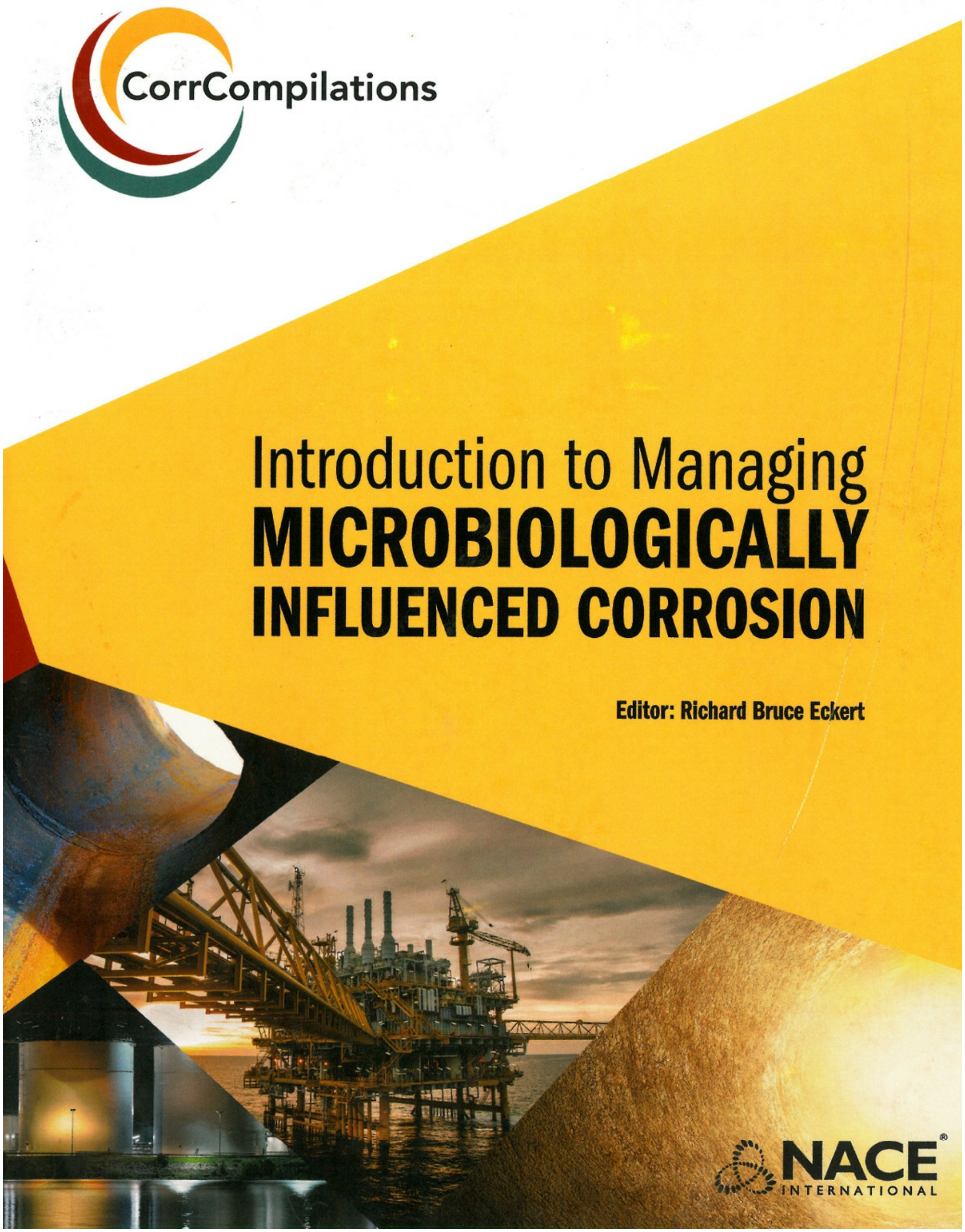

Introduction to Managing MICROBIOLOGICALLY INFLUENCED CORROSION

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NACE International

The Worldwide Corrosion Authority

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Introduction to MIC

Microbiologically influenced corrosion (MIC) is typically defined as Corrosion affected by the presence or activity, or both, of microorganisms.

MIC, like all corrosion mechanisms, is also influenced by a number of other factors such as materials properties, chemical composition of the environment, flow conditions, temperature, accumulation of solid deposits, operational variations, maintenance practices, and the use of mitigation chemicals. MIC can also occur in conjunction with other abiotic corrosion mechanisms. Since these variables can all influence corrosion, MIC cannot be viewed solely in terms of microbiology; ultimately, all of the factors supporting the corrosion mechanism in any given situation need to be considered.

The papers and articles included in this NACE International MIC CorrCompilation were assembled to help walk the reader through the process of assessing the threat of MIC, identifying and applying preventive and mitigative measures, and monitoring the effectiveness of mitigation. This compilation is organized by main sections that follow this process. This "assess-mitigate-monitor" process is a central part of a corrosion management system (CMS) and it can be applied to manage any type of corrosion threat mechanism.

The content of this CorrCompilation includes a wide range of topics including internal and external MIC, state-of-the-art molecular assessment techniques and practical corrosion monitoring methods, biocide application and cathodic protection, MIC in oil and gas-gathering systems and municipal waste handling facilities, and MIC of carbon steel and corrosion-resistant alloys, to name a few. However, since MIC is not only affected by microorganisms, the included papers also explore the effects of flow rate, under deposit corrosion (UDC), inhibitory properties of crude oil, and materials composition. Effective management of corrosion threats in large, complex assets is often attained through the use of tools such as MIC susceptibility models, corrosion prediction models, risk-based inspection (RBI) programs, and guidelines for establishing a CMS. Papers to address these topics are also included in this compilation. While MIC is not a simple subject to cover with a relatively short list of documents, this MIC publication provides exposure to some of the key topics needed to understand and control MIC.

The first article in the Introduction section, "A Closer Look at Microbiologically Influenced Corrosion," was published in Materials Performance in January 2014. In this feature article, industry MIC experts address some key questions and provide their insights on MIC identification and mitigation.

The second paper, "Practical Aspects of MIC Detection, Monitoring and Management in the Oil and Gas Industry," from CORROSION 2014, provides an overview of the corrosion management process for MIC.

The next two articles in this section were a two-part series published in Materials Performance in March and April 2004; "Expert Consensus on MIC Prevention and Monitoring—Part 1" and "Expert Consensus on MIC: Failure Analysis and Control—Part 2." Both articles were prepared with input from NACE Task Group 304 and although they date back 10 years, they still contain some very practical advice. For example, in the Part 1 article, the author writes, "The most important thing to remember about bacterial counts is that the actual numbers often are virtually meaningless..." which is something that corrosion engineers often still seem to forget.

The fifth article in this section, "Guide for the Investigation of MIC," appeared 30 years ago in the

August 1984 issue of Materials Performance. A sidebar to the article points out, "Through the efforts of NACE Task Group T-3J and others, microbiologically induced corrosion has been identified as a serious problem." This statement provides some interesting historical context in that MIC was only beginning to be accepted by industry as a viable corrosion mechanism in the 1980s. The discussion section of the article points out the importance of understanding the corrosive environment in view of the effects of pH, redox potential, temperature, and microbial energy sources, which is still relevant today.

MIC is a surface phenomenon, since microorganisms exist within a biofilm attached to the corroding surface. Often the biofilm is normally involved with, or encompassed by, other organic and inorganic deposits on the surface. The sixth paper, "Under Deposit Corrosion (UDC) in the Oil and Gas Industry: A Review of Mechanisms, Testing and Mitigation," points out some of the ways by which surface deposits can influence localized corrosion without the influence of microorganisms or biofilms. This paper from CORROSION 2012 also points out that MIC and UDC are often reported to occur in combination and it emphasizes that UDC is a general term that describes corrosion associated with deposits, which could be caused by a variety underlying corrosion mechanisms.

The seventh paper, "Categorization of Crude Oils Based on Their Ability to Inhibit Corrosion and Alter the Steel Wettability," provides a reminder that crude oil can affect surface conditions in ways that potentially influence the likelihood or severity of MIC. Although this CORROSION 2014 paper did not specifically consider biofilm attachment, a surface that is oil-wet may be less prone to biofilm attachment/ growth. Regardless of the environment, the paper is an example of how the abiotic effect of the environment on the corroding surface needs to be considered when assessing MIC or any corrosion mechanism.

The last paper in this section, "MIC: Managing Risk and Uncertainties," was presented at the Middle East Corrosion Conference and Exhibition in 2012. This paper provides an overview of the state of various MIC susceptibility/risk models and identifies where gaps still exist. The paper also identifies new technologies that are being applied to advance the understanding of MIC. In the conclusion, the author identifies a vital component of MIC management: "It is important that we link the science of microbiology to the sciences of electrochemistry and metallurgy in order to identify parameters that will have meaning in assessing internal MIC risk and generating predictive models." Thirty years ago, similar thoughts appeared in Materials Performance: "A great deal of combined work by the corrosion engineer and microbiologist remains to be done before the role of bacteria will be completely understood." In spite of the many advances made in understanding MIC since the 1980s, more collaborative work in corrosion and microbiology science is needed.

MIC is truly a multi-disciplinary subject, requiring the collaboration of corrosion, materials, microbiology, chemical treatment, and operations experts to advance our understanding of this phenomenon. For those seeking to understand and control the corrosion threat of MIC in their pipelines, processing facilities, cooling towers, and other assets, the greatest chance of success will be found through the collaboration of these disciplines.

A Closer Look at Microbiologically Influenced Corrosion
Materials Performance Roundtable Q & A

Kathy Riggs Larsen, Associate Editor

Meet the Panelists

Richard Eckert is a principal engineer—corrosion management at Det Norske Veritas (U.S.A.), Inc., in Dublin, Ohio. He has been involved with pipeline corrosion/failure investigation and forensic corrosion engineering for over 30 years. ANACE memberfor more than 20 years, Eckert has a B.S. degree in engineering metallurgy from Western Michigan University, is a NACE-certified Senior Internal Corrosion Technologist, and currently serves as chair of the NACE Books Committee, vice chair of the NACE Publications Committee, and is a member of the NACE Institute Certification Commission. He is chair of NACE Task Group (TG) 254. Eckert received the NACE Presidential Achievement Award in 2004.

Gary Jenneman is a principal scientist within the Global Production Excellence group of ConocoPhil- lips in Bartlesville, Oklahoma, where he has worked for the past 26 years. Jenneman has held various technical and supervisory positions in the areas of corrosion and oilfield microbiology. He holds a Ph.D. in microbiology from the University of Oklahoma and has 12 U.S. patents and numerous publications in the areas of microbiologi- cally enhanced oil recovery, MIC, reservoir souring, and biodesulfurization. As a NACE member, he has served on various NACE technical committees and panels over the past 15 years.

Sylvie Le Borgne is a professor researcher in the Department of Process and Technology at the Metropolitan Autonomous University at Mexico City, Mexico. Some of her research interests are in environmental microbiology, biocorrosion, and biodeterioration, as well as other topics in the area of biotechnology. She has been directly involved in petroleum biotechnology from 1999 to 2005. She was a recipient of the Carlos Casas Campillo prize in 2004, given by the Mexican Society of Biotechnology and Bioengineering to young researchers under 36 years old.

Jason S. Lee has worked as a materials engineer since 2001 at the U.S. Naval Research Laboratory in Stennis Space Center, Mississippi. A NACE member since 1999, Lee has chaired numerous MIC technical symposia and is currently vice chair of Technology Exchange Group (TEG) 187X. His research for the Navy focuses on the basic science aspects of MIC, computational corrosion modeling, improved fundamental understanding of the localized corrosion, and electrochemistry of metals and alloys exposed to marine environments. Lee received his B.S. degree in chemistry and cellular/molecular biology from the University of Michigan, and his M.S. and his Ph.D. degrees in materials science and engineering from the University of Virginia.

Brenda J. Little, FNACE, is a senior scientist for marine molecular processes at the Naval Research Laboratory in Stennis Space Center, Mississippi. She has worked on MIC projects for the U.S. Department of Transportation and the U.S. Army Corps of Engineers, and has served as a consultant to NASA. In addition to her accomplishments in basic research, Little also works on U.S. Navy assets to identify and control MIC. Her research has been used to determine the cause of corrosion failures in weapons systems, seawater piping systems, storage tanks, and other U.S. Navy equipment.

Torben Lund Skovhus is project manager at Det Nor- ske Veritas (DNV GL) in the Corrosion Management & Tech n ica I Advisory Group in Bergen, Norway. For almost 10 years he has been working with DTI Oil & Gas as a consultant and oilfield microbiologist for oil and gas operators and chemical vendors worldwide. He is an author of more than 30 technical and scientific articles related to molecular biology, oilfield microbiology, corrosion management, reservoir souring, and MIC. He is the editor of three books and the founder of the International Symposium on Applied Microbiology and Molecular Biology in Oil Systems (ISMOS). He has a M.S. degree in biology and a Ph.D. from the Microbiology Department at University of Aarhus, Denmark. A NACE member, he is the chair of NACE TEG 286X.

Feature Article

Microbiologically influenced corrosion (MIC) refers to corrosion caused by the presence and activities of microorganisms— microalgae, bacteria, and fungi. While microorganisms do not produce unique types of corrosion, they can accelerate corrosion reactions or shift corrosion mechanisms. Microbial action has been identified as a contributor to rapid corrosion of metals and